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National Wildfire
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United States
Department of Interior

National Association of
State Foresters

Field Quality Control of Fire Retardant Chemicals

Prepared by:
NWCG Fire Chemicals
Working Team

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Field Quality Control of Fire Retardant Chemicals

A Publication of the
National Wildfire Coordinating Group

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United States
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State Foresters

APRIL 1981

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FOREWORD

This National Wildfire Coordinating Group (NWCG) Field Quality Control of Fire Retardant Chemicals Guide provides information needed for cost effectiveness and efficient management of the Fire Retardant Chemical Program.

Preparation of this Guide was completed April 1981, at San Dimas, California.

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Fire Retardant Chemical Manufacturers
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San Dimas Equipment Development Center

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In recent years, when sizable wildfires have frequently broken out in many sections of the country, the nationwide annual use of fire retardant chemicals has been as high as 25 million gal (94,635 kl). Indeed, some Federal and various State firefighting organizations have each recorded the application of over 6 million gal (22,712 kl) in one fire season. If a conservative cost estimate of 35¢/gal (3.785 l) for the chemicals is used, the national retardant bill for 1 yr could be as high as $8.75 million. Some studies indicate that product cost may account for about half of the total cost of applying a gal (3.785 l) of retardant on a fire. This dollar magnitude highlights the need for careful management and adequate quality control to assure that the retardant program is cost effective.

Retardant chemicals are approved for use in aircraft or ground equipment according to specifications of the Forest Service, United States Department of Agriculture. The individual requirements of these specifications work together to insure availability of products that are effective fire control tools. Most of the requirements contain a specific permissible range of selected physical or chemical characteristics which, if maintained in field-mixed retardants, will insure that the product continues to perform at an effective level. Besides altering effectiveness, deviations from these requirement values can also increase corrosivity, adversely affect storeability and pumpability, and cause general degradation of the products usefulness. Formulation of these materials is based on a very specific product-to-water ratio and it is often the degree of control over this relationship that determines the quality of the final field mix.

A number of well-established but uncomplicated tests, requiring the use of simple measuring equipment, are available for the air attack base manager to use in estimating how well field-mixed retardants meet the Forest Service's requirements. Since these tests are not carried out in a rigid laboratory environment, they are best described as ***Field Quality Control*** procedures. Step-by-step instructions on how to perform these tests and how to interpret the results are the principal subjects of this publication.

Unless retardants are properly inhibited, they can cause corrosion and subsequent failure of some metals used in aircraft, fire engines, and retardant handling-mixing-storage systems. The Forest Service specifications prescribe corrosion limits which cannot be exceeded. The most effective level of corrosion inhibitor required to meet those limits for any single formulation is based on the average or nominal values for other requirements, as determined during the formal qualification and approval process. Field-mixed products must also test to these same values if corrosion protection is to be assured. Thus, factors which are related to effectiveness, such as viscosity and salt content, are also indexes to the level of corrosion protection that is being provided. If the measured characteristics of field-mixed retardants show them to be below standard then the risk of appreciable and damaging corrosion to aircraft is greatly increased. Conversely, research has clearly demonstrated that in some instances corrosion inhibition can reach a maximum and then decrease as inhibitor concentration ***increases.*** These relationships are complex but they do offer straightforward support for the maintenance of standard values in retardant mixes as a valid and important part of corrosion control efforts. Field quality control techniques are the tools available to the base manager for this job.

Appendices I and II of this publication are Forest Service Research Notes that list ranges for various characteristics of retardant chemicals that are addressed in two Forest Service specifications (not appended, but available from USDA Forest Service, P. O. Box 2417, Washington, D.C., 20013, Attn: Director—Aviation and Fire Management). In some cases, the tolerances in the Research Notes are more restrictive than the value ranges cited in the specification. Another document, ***Chemicals for Forest Fire Fighting*** [1/] (3d ed., 1977) extensively covers retardant types and their composition, environmental considerations, handling equipment, and application. It also has a chapter on "Quality Control in the Field."

The material in this National Wildfire Coordinating Group (NWCG) guide provides a framework for field personnel to establish and operate an informal and inexpensive chemistry laboratory at locations where retardant chemicals are mixed for either aerial or ground application. By obtaining the specified equipment and following the directions in this guide, the quality of mixed retardant chemicals ("slurries") can be checked and verified. By taking the corrective actions that are given, the viscosity, salt content, or specific weight of a slurry that is not within established ranges can almost always be brought back to specification levels.

Much useful information, which fully complements this Quality Control Guide, is contained in the National Wildfire Coordinating Group publication of September 1980 titled ***"Airtanker Base Planning Guide."*** [2/]

[1/] Available from the National Fire Protection Association, 470 Atlantic Ave., Boston, MA 02210.

[2/] Available from USDA Forest Service, Equipment Development Center, 444 E. Bonita, San Dimas, CA 91773.

SPECIFICATIONS AND APPROVED FORMULATIONS

Presently, there are specifications only for the long-term retardant chemicals, which inhibit the spread of flame even after the water they were mixed with has evaporated. The following lengthy documents, one for dry and one for liquid chemical products, establish quality standards and fire control effectiveness requirements for long-term retardants:

- Specification for Retardant, Forest Fire, Dry Chemical, for Aircraft or Ground Application; Interim Specification 5100-00301a, February 1975; 28 p. (including Amendment No. 2, April 1979); USDA Forest Service, Equipment Development Center, San Dimas, CA 91773.

- Specification for Retardant, Forest Fire, Liquid Chemical, for Aircraft or Ground Application; Interim Specification 5100-00302b, February 1975; 22 p. (including Amendment No. 1, June 1977); USDA Forest Service, Equipment Development Center, San Dimas, CA 91773.

Appendix III lists commercially available retardant, formulations that, as of the date indicated on it, have been qualified and approved by the Forest Service for either aerial or ground application, in accordance with the two existing specifications. The mix ratios specified in the table are all-important, since the listed retardant products have been tested and qualified only at those ratios. The retardants are not approved for use at other concentrations.

Appendix III is part of a regularly issued "Retardant Status Report" which is updated quarterly and is available from USDA Forest Service, P. O. Box 2417, Washington, D.C., 20013, Attn: Director—Aviation and Fire Management.

The manufacturers of the products listed in Appendix III can be contacted for product service and technical information as follows:

For Fire-Trol® [3] products

Chemonics Industries — **P. O. Box 21568, Phoenix, AZ 85036, Telephone: 602/262-5401**

Chemonics Industries — **P. O. Box 277, Orland, CA 95963, Telephone: 916/865-4932** *(24-hr)*

For Phos-Chek® [4] products

Monsanto Company — **810 East Main Street, Ontario, CA 91761, Telephone: 213/864-6220** *(24-hr)* **or 714/983-0772**

The fire retardant salts used in the approved formulations are also used as agricultural fertilizers. To provide a better understanding of what is in these products, here are brief descriptive summaries:

- *Fire-Trol 100 retardant.* The retardant salt is ammonium sulphate. The viscosity of this product is developed by shearing a swelling clay, usually while mixing in 500- to 1,000-gal (1893 to 3785 l) mixers. Ferric (iron) oxide, a pure form of rust, is used as a coloring agent. A corrosion inhibitor is added to protect the tanks and aircraft.

- *Fire-Trol 931-L retardant.* This product is one of a family of liquid concentrate (LC) retardants whose principal salt is ammonium polyphosphate (APP), a liquid 10-34-0 fertilizer. A small amount of attapulgite clay is combined with ferric oxide and a dye to provide a deep red color. A corrosion inhibitor is also added. Mixing is usually done directly through a high-volume, low-pressure pump, since the clay is an abrasive that quickly wears out high-pressure, positive-displacement pumps or the pump seals of high-pressure centrifugal pumps.

- *Phos-Chek XA retardant:* The retardant salt is diammonium phosphate (DAP) and the thickener is guar gum from the guar bean. The formulation is complex and contains corrosion and spoilage inhibitors, anti-

[3] ® Fire-Trol, registered trademark of Chemonics Industries, Phoenix, AZ.

[4] ® Phos-Chek, registered trademark of Monsanto Company, St. Louis, MO.

foaming compounds, fugitive [5/] or non-fugitive coloring agents, and flow conditioners. Mixing is usually accomplished by proportioning the dry powder through an eductor or a venturi-like waterflow device.

- *Phos-Chek 259-R or 259-F retardant:* DAP is again the retardant salt, but at a little higher concentration than in Phos-Chek XA. Only a very small amount of thickener is used. The rest of the formulation is the same as that of XA; mixing is accomplished as above. Also, Phos-Chek 259 can be easily mixed by agitating or forcefully recirculating it in a tank of water.

- *Fire-Trol 934-L retardant:* This is another LC, but with no clay to damage the high-pressure pumps in ground tankers (engines). Since there is no clay that would keep ferric oxide in suspension, it also is left out of this formulation. This product has a light blue color from the corrosion inhibitor that it contains.

IMPORTANCE OF MEASURING QUALITY OF FIELD-MIXED RETARDANTS

Later sections of this guide specify selected physical characteristics that are to be measured for field-mixed retardants. Specific values or ranges are also stated. If the values for these field measurements fall within the stated limits then it is highly likely that the retardant will meet all requirements of the formal specifications and it will provide maximum protection, effectiveness, and performance. Mixtures with one or several values that fall outside the limits of this guide can cause a number of problems.

- **Mixtures that have values *higher* than those in in the required ranges may:**

  —Cost more per gallon than they should.

  —Increase the probability of applying retardant to the fuels in much greater quantity than necessary to do the control job.

  —Be too viscous and appreciably reduce flow rates in loading systems.

  —Damage pumping equipment by causing cavitation and hammering.

  —Decrease wet storage capacity because of increased precipitation of solids and a tendency to accumulate large quantities of unpumpable materials—particularly if clay thickeners are undersheared.

  —Increase the danger to ground personnel from breakage of limbs and tree tops by air drops of highly viscous material—particularly if gum-thickened retardants are involved.

- **Mixtures that have values *lower* than those in the required ranges may:**

  —Not be fully fire control effective because of low salt content.

  —Not retain enough retardant on the fuel to be effective.

  —Not produce the most effective pattern because of lack of cohesion.

  —Separate more readily in wet storage.

  —Not be as resistant to spoilage or be as well inhibited against corrosion as standard slurries because key formula elements are reduced.

Corrosion Control Information and Guidelines

A few guidelines as to corrosion problems and prevention methods follow. These are important, since at a well-managed mixing facility there should be frequent checks for any corrosion that is being caused by retardant chemicals. Some current research information on tank treatment materials is in technical laboratory reports. Field managers will find more useful information in Ocean City Research Corporation's *"User Guideline Manual for Control of Fire Retardant Corrosion."* This publication, currently in review draft form and dated December 1976, was prepared for the USDA Forest Service, Intermountain Forest & Range Experiment

[5/] Fugitive coloring agents fade to a neutral tint after several weeks of exposure to direct sunlight.

Station, Northern Forest Fire Laboratory, Drawer G, Missoula, MT 59801 Another source of information, which is recognized as an authoritative source on procedures for control of retardant-caused corrosion, is FAA Advisory No. 43-4, "*Corrosion Control for Aircraft.*"

- Frequently monitor the corrosion status of all equipment. Report unusual conditions or severe attacks. Document the success or failure of corrosion prevention measures; i.e., how well a particular tank, pipe treatment, or painting method stood up.

- Before using *any* tank cleaning system or paints or coatings in or on tanks, review applicable safety instructions found in governmental safety regulations, or elsewhere, and follow also the manufacturers' recommended safety practices. See that the coating is not capable of damaging the retardant to be stored.

- A major failing of tank ventilation systems now in use is inadequate air venting around the edge of the tank top. Gasses develop at the top of slurry storage tanks and are believed to cause corrosion when using retardants containing ammonium sulfate. There should be enough vents of such a size as to permit air inflow that is greater than the outflow through the center ventilator or exhaust device.

FIELD TESTING, RECORDING, AND CORRECTING

Field Testing

Of the various qualification requirements for retardant chemicals spelled out in the two specifications, a few lend themselves to reasonably simple test procedures that can be performed in the field. The following is a comparison of field methods versus tests to be accomplished in a regular laboratory environment.

- Viscosity—Test with a Marsh funnel instead of with a Brookfield viscometer.

- Salt content—Measure specific gravity with a hydrometer—to represent salt content—instead of determining it by chemical analysis.

- Specific weight—Weigh a known volume on a "postal" scale instead of using a pycnometer.

- pH—Test for pH (rarely needed) with test paper instead of with a pH meter.

For liquid chemicals only, a portion of the formal separation test can be accomplished in the field by taking fresh-mixed samples and observing changes. After 4 hr, there should be no more than 30 percent separation of volume, as measured with a linear scale.

The required mixed retardant (slurry) characteristics and associated operational use values are grouped by product name in this section of the guide. Acceptable operational ranges for viscosity are from USDA Forest Service Research Note INT-205 (appendix I). Those for salt content and specific weight are from USDA Forest Service Research Note INT-138 (appendix II); the specific weights are from table 1 on page 3. Salt content values, in terms of percent solution by weight, are from the same table, with the exception of the figure for Fire-Trol 931-L, which is from table 7, page 13, as revised March 25, 1975. Weights of products added per gal (3.785 l) of water and equivalent weights or product per gal (3.785 l) of slurry are from table 3.1 of ***Chemicals for Forest Fire Fighting*** (see [1/]) and from unpublished data of C. W. George, USDA Forest Service, Northern Forest Fire Laboratory, Missoula, Mont.

Recording Quality Control Measurements

Each retardant mixing base or station should maintain permanent records of quality control measurements. As a minimum, record the date, solution temperature, Marsh funnel time, viscosity, specific gravity, and salt content along with product identification data. Such permanent records are useful when studying product quality trends, providing essential background to newly assigned personnel, or documenting incidents involving retardant application by airtankers or engines.

Correcting Non-standard Mixes

If the values for viscosity, salt content, and specific weight are in the desired ranges, then the base or station manager will usually need only to duplicate the water/retardant proportions and the specific mixing procedures to continue producing a standard mix. However, if the measured values fall outside the acceptable ranges, then the manager must determine the source of the problem and take steps to bring the mixture back to a standard level.

Some problems may be related to on-site proportioning, or to the technique of mixing, and may be easily corrected. Other problems have far more subtle causes, which may be very difficult to detect and correct without outside help from technical experts. Information presented in each of the product discussions that follow helps identify what course of action to take in order to resolve some of these problems.

FIRE-TROL 100 RETARDANT

Required Performance Characteristics

- Viscosity—1500 to 2500 centipoise (cP).
- Salt content—15 percent minimum $(NH_4)_2SO_4$ solution by weight.
- Specific weight—9.5 lb/gal (1.14 g/cm^3) maximum.
- pH—5.5 to 8.0.

Expected Operational Values

- Viscosity—Marsh funnel time, 20 to 40 sec through the large tip—or 1530 to 2480 cP. Average = 27 sec or 2000 cP. Marsh funnel time, 63 to 120+ sec through the small tip—or 1541 to 1960 cP. Average = 120 sec or 2000 cP.
- Salt content at 80° F (27° C)—1.095 to 1.110 specific gravity units—or 14.8 to 17.0 percent $(NH_4)_2SO_4$ by weight. Average = 1.101 or 15.6 percent.
- Specific weight—9.3 to 9.4 lb/gal (1.11 to 1.13 g/cm^3). This corresponds to 2.78 lb (1.26 kg) of Fire-Trol 100 retardant added per gal (3.785 l) of water, which creates a solution with 2.32 lb (1.05 kg) of Fire-Trol 100 retardant per gal (3.785 l) of slurry.

Test Instruments and Measuring Devices

Have the following on hand:

1. Marsh funnel with a large orifice: 0.269 ± 0.002 in (0.683 ± 0.005 cm) ID. (Available from Western Fire Equipment Co., 440 Valley Drive, Brisbane, CA 94005—catalog No. 12512.) If a small orifice must also be used, it shall have a 0.187 ± 0.002 in (0.475 ± 0.005 cm) ID.[6/]

2. A container with a level mark, or volume determined, at precisely 1 qt (946.4 ml). A 1,000-ml (1.06-qt) Nalge polypropylene plastic graduated cylinder can be marked at the 1-qt (946.4-ml) level. (Available from VWR Scientific Co.—catalog No. 24776-144; or Fisher Scientific Co.—catalog No. 8-572G.)

3. A stopwatch or a watch with a sweep-second hand.

4. A hydrometer with a range of 1.060 to 1.130 specific gravity units, approximately 6 in (150 mm) long with 0.001-mm divisions. (Available from Fisher Scientific Co.—catalog No. 11-556G.)

5. A 100-cm^3 Pyrex No. 9820 test tube, 25 mm OD and 200 mm long, as a filtrate container for the small hydrometers. (Available from Fisher Scientific Co.—catalog No. 14-957N.) A satisfactory substitute is a slender bottle at least 6 in (150 mm) tall. The test tube requires a minimum of filtrate and provides a quick, handy way to collect the right-size sample for the hydrometer.

6. An all-metal, dial-type thermometer to measure slurry temperatures, range 25° to 125° F (−4° to 52° C). (Available from VWR Scientific Co.—catalog No. 61048-055.) Or one with range 0° to 180° F (−18° to 82° C). (Available from Fisher Scientific Co.—catalog No. 15-076B.)

7. A clean pail or bucket for collecting the test sample.

[6/] Deviations of more than 0.002 in (0.005 cm) from the standard Marsh funnel tip size can cause substantial viscosity measurement errors. The listed vendor supplies Marsh funnels precisely reamed to the specific inside diameter (ID). A competent machinist can also manufacture a rod-shaped gauge to measure the orifice size on a go/no-go basis. Tolerances of ±0.0005 in (0.0013 cm) are practical.

8. A clean jar or can of at least one quart capacity for collecting filtrate.

9. Large filter papers and funnel. (Available as 12 in [300 mm] diameter drip coffee maker filters and 6 in [150 mm] diameter filter holder.)

10. An 8- to 10-in (20- to 25-cm) square of nylon window screen, to place between filter paper and funnel wall to speed up flow. (Available at hardware and builders' supply stores.)

Selecting the Sample for Testing

Perform retardant testing on a pailful of slurry that represents the average characteristics of the material ***in the storage tanks.*** Before testing:

1. Recirculate the product in the tanks, 24 hr after a major mixing operation, for 10 min (minimum) and draw a sample from a recirculation line or pump.

2. During periods when little material is pumped, recirculate tanks and sample them at least every 7 days.

3. If significant deterioration is discovered in stored material, then (a) dip or draw a sample of bad material and hold for instructions, and (b) notify the manufacturer and your supervisor of the conditions.

4. During mixing operations, take control samples often enough to insure that measured values of tank samples, taken from material aged at least 24 hr, meet stated requirements.

5. Do not use as a sample slurry that has rested in lines, pumps, or hoses for long periods of time or that has been subjected to heating by the sun or to extended drying.

6. End-of-loading hose samples may be adequate, if enough stored material has been pumped out to insure that old slurry is completely purged from the piping.

Test Procedures

Test the samples in accordance with the following procedures:

Specific Weight
Specific weight measurement is optional, but may be useful in helping explain the reasons for variations from the standards. A small "postal" scale may be used to measure the net weight of a known volume of slurry. The following tabulation may be used to convert net weight to specific weight for a 1-qt (946.4-ml) sample.

Viscosity
Measure viscosity with the Marsh funnel (large or small tip), the measured 1-qt (946.4-ml) container, and a watch readable to 1 sec.

Net weight	Specific weight lb/gal	Specific weight g/cm^3	Net weight	Specific weight lb/gal	Specific weight g/cm^3
2 lb ½ oz	8.1	0.97	2 lb 4½ oz	9.1	1.09
2 lb 1 oz	8.2	0.98	2 lb 5 oz	9.2	1.10
2 lb 1½ oz	8.4	1.01	2 lb 5½ oz	9.4	1.13
2 lb 2 oz	8.5	1.02	2 lb 6 oz	9.5	1.14
2 lb 2½ oz	8.6	1.03	2 lb 7½ oz	9.6	1.15
2 lb 3 oz	8.8	1.05	2 lb 7 oz	9.8	1.17
2 lb 3½ oz	8.9	1.07	2 lb 7½ oz	9.9	1.19
2 lb 4 oz	9.0	1.08	2 lb 8 oz	10.0	1.20

NOTE: If the weight of the 1-qt (946.4-ml) sample is outside the above range, convert the net weight to specific weight by taking the number of whole pounds, plus the ounces divided by 16, and multiplying this by 4; or 4 x (whole lb + oz/16).

Acceptable values for Fire-Trol 100 retardant are 9.3 to 9.4 lb/gal (1.11 to 1.13 g/cm^3).

1. Let the sample rest in the bucket until excessive air bubbles have disappeared (about ½ hr). Tap the bucket gently on the ground to shake loose remaining bubbles.

2. Be sure the funnel is clean and dry and is held truly vertical.

3. Cover the funnel tip with a finger and pour the retardant ***through the screen*** until the fluid level ***exactly*** reaches the bottom of the screen.

4. Measure the time (in minutes and seconds) it takes flow from the funnel orifice to fill the measuring container to the 1-qt (946.4-ml) mark. Use only the retardant originally contained in the funnel—***do not*** add more during the measuring process.

5. Use the dial-type thermometer to measure solution temperature. Record it. If a temperature correction table has been prepared, use it to determine the adjusted funnel time.

6. Using Research Note INT-205, look up the measured time in the left-hand side of the Marsh funnel time table. Read the proper column to the right to find viscosity in centipoise. The boxes indicate satisfactory operational use ranges. For Fire-Trol 100 retardant the satisfactory ranges are 20 to 40 sec with the large tip, or 1530 to 2480 cP (average is 27 sec or 2000 cP). Using the small tip, the satisfactory ranges are 63 to over 120 sec, or 1541 to 1960 cP. (Average is 120 sec, or 2000 cP.)

Salt Content

Salt content is determined by measuring specific gravity with the hydrometer. Fire-Trol 100 retardant contains swelling clays that thicken the slurry enough to prevent direct readings. Non-viscous samples ***must*** be obtained by filtering the thickened product. Take hydrometer readings of the ***filtered solution.***

CAUTION: **Never attempt to take hydrometer readings in thickened solutions. Laboratory tests demonstrate that the hydrometer will never reach a true value and that there is no meaningful relationship of such thick-solution readings to those obtained in non-viscous samples.**

To prepare the filtrate and test for salt content:

1. Set the filter funnel into a clean can or jar.

2. Place the nylon screen in the funnel and press center down towards funnel tip; then press the filter paper down on top of the screen. Do not tear paper.

3. Slowly pour retardant from the sample pail into the filter cone until it is full. Do not let retardant spill between filter paper and screen.

4. Filtrate should be clear, with a yellow tint, and free of any solids. Collect enough to fill the 100-cm^3 test tube about three-quarters full.

5. Use the dial-type thermometer to measure solution temperature in the test tube. Record it.

6. Place the hydrometer in the filtrate, read specific gravity units, and record. Be sure the bulb is fully and freely floating and no air bubbles are supporting it. Readings are always in the form of 1.XXX, and observation to the nearest 0.001 is normal.

A correction to specific gravity may be needed if solution temperature varies significantly from 80° F (27° C). This correction is the same for all retardants and is as follows:

Solution temperature	Add to or subtract from hydrometer reading
98° to 102° F (37° to 39° C)	Add 0.004
93° to 97° F (34° to 36° C)	Add 0.003
88° to 92° F (31° to 33° C)	Add 0.002
83° to 87° F (28° to 30½° C)	Add 0.001
78° to 82° F (25½° to 28° C)	None
73° to 77° F (23° to 25° C)	Subtract 0.001
68° to 72° F (20° to 22° C)	Subtract 0.002
63° to 67° F (17° to 19° C)	Subtract 0.003
58° to 62° F (14° to 17° C)	Subtract 0.004
53° to 57° F (12° to 14° C)	Subtract 0.005
48° to 52° F (9° to 11° C)	Subtract 0.006

Using Research Note INT-138, look up the corrected specific gravity reading in the left-hand side of the table. ***Be sure you are using the correct table*** (table 6 for Fire-Trol 100 retardant). Read salt content or salt equivalency from the proper columns. If salt content is not of average value, the two right-hand columns show amount of water or product needed for correction. The boxes indicate satisfactory operational use ranges. For Fire-Trol 100 retardant, the acceptable range is 1.095 to 1.110 specific gravity units (average is 1.101).

Recommended Corrective Actions

The correct salt content for the Fire-Trol 100 slurry depends upon the ratio of product-to-water, while the viscosity is dependent on the total amount of energy—in terms of shear—delivered to the slurry by the batch mixer impellers. This energy input is governed by how fast it is delivered (shaft rpm, usually a constant) and for how long (mix time, which can be varied). Thus, corrections can be made as follows:

Conditions		Corrective action	
Salt	Viscosity	Product-to-water ratio	Mix time
Low	Low	Increase	Don't change
Low	Normal	Increase	Decrease some
Low	High	Increase	Decrease a lot
Normal	Low	Don't change	Increase
Normal	High	Don't change	Decrease
High	Low	Decrease	Increase some or don't change, initially
High	Normal	Decrease	Don't change, initially
High	High	Decrease	Decrease some, initially

When changing salt level, be cautious about major changes in mix time. Adding a little shear energy after the proper salt level is reached is much easier to accomplish than thinning a "too-thick" mix.

FIRE-TROL 931-L RETARDANT

Required Performance Characteristics

- Viscosity—200 centipoise (cP).
- Salt content—30 percent minimum P_2O_5 equivalent in concentrate form.
- Specific weight—9.5 lb/gal (1.14 g/cm^3) maximum.
- pH—5.5 to 8.0.

Expected Operational Values

- Viscosity—Marsh funnel time, about 10 sec through small tip (accuracy is questionable)—or 100 cP.
- Salt content at 80° F (27° C)—1.090 to 1.105 specific gravity units—or 14.9 to 17.2 percent $(NH_4)_2HPO_4$ by weight. Average = 1.096 units or 15.8 percent.
- Specific weight—9.1 to 9.2 lb/gal (1.09 to 1.10 g/cm^3). This corresponds to 2.93 to 3.05 lb (1.33 to 1.38 kg) of Fire-Trol 931-L retardant added per gal (3.785 l) of water, which creates a solution with 2.34 to 2.44 lb (1.06 to 1.11 kg) of Fire-Trol 931-L retardant per gal (3.785 l) of slurry.

Test Instruments and Measuring Devices

Have the following on hand:

1. Marsh funnel [7] with a small orifice; 0.187 ± 0.002 in (0.475 ± 0.005 cm) ID. [8] (Available from Western Fire Equipment Co., 440 Valley Drive, Brisbane, CA 94005—catalog No. 12512.)

2. A container [7] with a level mark, or volume determined, at precisely 1 qt (946.4 ml). A 1,000-ml (1.06 qt) Nalge polypropylene plastic graduated cylinder can be marked at the 1-qt (946.4 ml) level. (Available from VRW Scientific Co.—catalog No. 24776-144; or Fisher Scientific Co.—catalog No. 8-572G.)

3. A stopwatch or a watch with a sweep-second hand.[7]

4. A hydrometer with a range of 1.060 to 1.130 specific gravity units, approximately 6 in (150 mm) long with 0.001-mm divisions. (Available from Fisher Scientific Co.—catalog No. 11-556G.)

5. A 100-cm^3 Pyrex No. 9820 test tube, 25 mm OD and 200-mm long, as a filtrate container for the small hydrometers. (Available from Fisher Scientific Co.—catalog No. 14-957N.) A satisfactory substitute is a slender bottle at least 6 in (150 mm) tall. The test tube requires a minimum of filtrate and provides a quick, handy way to collect the right-size sample for the hydrometer.

6. An all-metal, dial-type thermometer to measure slurry temperatures, range 25° to 125° F (−4° to 52° C). (Available from VWR Scientific Co.—catalog No. 61048-055.) Or one with range 0° to 180° F (−18° to 82° C). (Available from Fisher Scientific Co.—catalog No. 15-076B.)

7. A clean pail or bucket for collecting the test sample.

8. A clean jar or can of at least one quart capacity for collecting filtrate.

9. Large filter papers and funnel. (Available as 12 in [300 mm] diameter drip coffee maker filters and 6 in [150 mm] diameter filter holder.)

10. An 8- to 10-in (20- to 25-cm) square of nylon window screen, to place between filter paper and funnel wall to speed up flow. (Available at hardware and builders' supply stores.)

Selecting the Sample for Testing

Perform retardant testing on a pailful of slurry taken from the end of the loading hose:

1. If significant deterioration is discovered in stored concentrate or in mixtures stored on aircraft for long periods of time then (a) dip or draw a sample of bad material and hold for instructions, and (b) notify the manufacturer and your supervisor of these conditions.

2. During mixing operations, take samples often enough to insure that average characteristics of the mix being loaded meet stated requirements.

3. Take samples from the end of the loading hose after enough new mix has been pumped to insure complete purging of old slurry from the piping.

Test Procedures

Test the samples in accordance with the following procedures:

Specific Weight

Specific weight measurement is optional, but may be useful in helping explain the reasons for variations from the standards. A small "postal" scale may be used to measure the net weight of a known volume of slurry. The following tabulation may be used to convert net weight to specific weight for a 1-qt (946.4-ml) sample. Fire-Trol 931-L retardant mixed at a 4:1 ratio weighs 9.1 to 9.2 lb/gal (1.09 to 1.10 g/cm^3).

Viscosity

Measure viscosity with the Marsh funnel (small tip only), the measured 1-qt (946.4-ml) container, and a watch readable to 1 sec.

1. Let the sample rest in the bucket until excessive air bubbles have disappeared (about ½ hr). Tap the bucket gently on the ground to shake loose remaining bubbles.

[7] Optional since the viscosity of Fire-Trol 931-L retardant is usually ***not*** measured.

[8] Deviations of more than 0.002 in (0.005 cm) from the standard Marsh funnel tip size can cause substantial viscosity measurement errors. The listed vendor supplies Marsh funnels precisely reamed to the specific inside diameter (ID). A competent machinist can also manufacture a rod-shaped gauge to measure the orifice size on a go/no-go basis. Tolerances of ± 0.0005 in (0.0013 cm) are practical.

Net weight	Specific weight lb/gal	g/cm^3	Net weight	Specific weight lb/gal	g/cm^3
2 lb ½ oz	8.1	0.97	2 lb 4½ oz	9.1	1.09
2 lb 1 oz	8.2	0.98	2 lb 5 oz	9.2	1.10
2 lb 1½ oz	8.4	1.01	2 lb 5½ oz	9.4	1.13
2 lb 2 oz	8.5	1.02	2 lb 6 oz	9.5	1.14
2 lb 2½ oz	8.6	1.03	2 lb 6½ oz	9.6	1.15
2 lb 3 oz	8.8	1.05	2 lb 7 oz	9.8	1.17
2 lb 3½ oz	8.9	1.07	2 lb 7½ oz	9.9	1.19
2 lb 4 oz	9.0	1.08	2 lb 8 oz	10.0	1.20

NOTE: If the weight of the 1-qt (946.4-ml) sample is outside the above range, convert the net weight to specific weight by taking the number of whole pounds, plus the ounces divided by 16, and multiplying this by 4; or 4 x (whole lb + oz/16).

Acceptable values for Fire-Trol 931-L retardant mixed at a 4:1 ratio are 9.1 to 9.2 lb/gal (1.09 to 1.10 g/cm^3).

2. Be sure the funnel is clean and dry and is held truly vertical.

3. Cover the funnel tip with a finger and pour the retardant ***through the screen*** until the fluid level ***exactly*** reaches the bottom of the screen.

4. Measure the time (in minutes and seconds) it takes flow from the funnel orifice to fill the measuring container to the 1-qt (946.4-ml) mark. Use only the retardant originally contained in the funnel—***do not*** add more during the measuring process.

5. Use the dial-type thermometer to measure solution temperature. Record it. If a temperature correction table has been prepared, use it to determine the adjusted funnel time.

6. Using Research Note INT-205, look up the measured time in the left-hand side of the Marsh funnel time table. Read the proper column to the right to find viscosity in centipoise. The boxes indicate satisfactory operational use ranges. For Fire-Trol 931-L retardant the satisfactory time is about 10 seconds.

Salt Content

Salt content is measured with the hydrometer. Fire-Trol 931-L retardant contains swelling clays that thicken the slurry enough to prevent direct readings. Non-viscous samples ***must*** be obtained by filtering the thickened product. Take hydrometer readings of the ***filtered solution.***

CAUTION: **Never attempt to take hydrometer readings in thickened solutions. Laboratory tests demonstrate that the hydrometer will never reach a true value and that there is no meaningful relationship of such thick solution readings to those obtained in non-viscous samples.**

To prepare the filtrate and test for salt content:

1. Set the filter funnel into a clean can or jar.

2. Place the nylon screen in the funnel and press center down towards funnel tip then press the filter paper down on top of the screen. Do not tear paper.

3. Slowly pour retardant from the sample pail into the filter cone until it is full. Do not let retardant spill between filter paper and screen.

4. Filtrate should be clear, with a reddish tint, and free of any solids. Collect enough to fill the 100-cm^3 test tube about three-quarters full.

5. Use the dial-type thermometer to measure solution temperature in the test tube. Record it.

6. Place the hydrometer in the filtrate, read specific gravity units and record. Be sure the bulb is fully and freely floating and no air bubbles are supporting it. Readings are always in the form of 1.XXX, and observation to the nearest 0.001 is normal.

A correction to specific gravity may be needed if solution temperature varies significantly from 80° F (27° C). This correction is the same for all retardants and is as follows:

Solution temperature	Add to or subtract from hydrometer reading
98° to 102° F (37° to 39° C)	Add 0.004
93° to 97° F (34° to 36° C)	Add 0.003
88° to 92° F (31° to 33° C)	Add 0.002
83° to 87° F (28° to 30½° C)	Add 0.001
78° to 82° F (25½° to 28° C)	None
73° to 77° F (23° to 25° C)	Subtract 0.001
68° to 72° F (20° to 22° C)	Subtract 0.002
63° to 67° F (17° to 19° C)	Subtract 0.003
58° to 62° F (14° to 17° C)	Subtract 0.004
53° to 57° F (12° to 14° C)	Subtract 0.005
48° to 52° F (9° to 11° C)	Subtract 0.006

Using Research Note INT-138, look up the corrected specific gravity reading in the left-hand side of the table. ***Be sure you are using the correct table*** (table 7 for Fire-Trol 931-L retardant). Read salt content or salt equivalency from the proper columns. If salt content is not of average value, the two right-hand columns show amounts of water or product needed for correction. The boxes indicate satisfactory operational use ranges. For Fire-Trol 931-L retardant the acceptable range is 1.090 to 1.105 specific gravity units (average is 1.096).

Recommended Corrective Actions

The quality of Fire-Trol 931-L retardant solution is almost exclusively a function of salt content. Simply increase or decrease the product-to-water ratio to produce normal salt values.

PHOS-CHEK XA RETARDANT

Required Performance Characteristics

- Viscosity—1000 to 2000 centipoise (cP).
- Salt content—10.0 percent minimum $(NH_4)_2HPO_4$ solution by weight.
- Specific weight—9.5 lb/gal (1.14 g/cm^3), maximum.
- pH—5.5 to 8.0.

Expected Operational Values

- Viscosity—Marsh funnel time, 45 to 65 sec at 75° F (24° C) through the large tip—or 1502 to 2067 cP. Average = 53 sec or 1750 cP.
- Salt content at 80° F (27° C)—1.065 to 1.080 specific gravity units—or 9.3 to 11.5 percent $(NH_4)_2HPO_4$ by weight. Average = 1.074 to 10.6 percent.
- Specific weight—8.9 lb/gal (1.07 g/cm^3). This corresponds to 1.14 lb (0.52 kg) of Phos-Chek XA retardant added per gal (3.785 l) of water, which creates a solution with 1.07 lb (0.49 kg) of Phos-Chek XA retardant per gal (3.785 l) of slurry.

Test Instruments and Measuring Devices

Have the following on hand:

1. Marsh funnel with a large orifice; 0.269 ± 0.002 in (0.683 ± 0.005 cm) ID. (Available from Western Fire Equipment Co., 440 Valley Drive, Brisbane, CA 94005—catalog No. 12512.) If a small orifice must also be used, it shall have a 0.187 ± 0.002 in (0.475 ± 0.005 cm) ID.[9/]

[9/] Deviations of more than 0.002 in (0.005 cm) from the standard Marsh funnel tip size can cause substantial viscosity measurement errors. The listed vendor supplies Marsh funnels precisely reamed to the specified inside diameter (ID). A competent machinist can manufacture a rod-shaped gauge to measure the orifice size on a go/no-go basis. Tolerances of ± 0.0005 (0.0013 cm) are practical.

2. A container with a level mark, or volume determined, at precisely 1-qt (946.4-ml). A 1,000-ml (1.06-qt) Nalge polypropylene plastic graduated cylinder can be marked at the 1-qt (946.4-ml) level. (Available from VWR Scientific—catalog No. 24776-144; or Fisher Scientific Co.—catalog No. 8-572G.)

3. A stopwatch or a watch with a sweep-second hand.

4. A hydrometer with a range of 1.060 to 1.130 specific gravity units, approximately 6 in (150 mm) long with 0.001-mm divisions. (Available from Fisher Scientific Co.—catalog No. 11-556G.)

5. A 100-cm^3 test tube for preparing the thinned solution of retardant which will also serve as the measuring device for the small hydrometer. (Available from Fisher Scientific Co.—catalog No. 14-957N, Pyrex brand [9820], OD of 25 mm and length of 200 mm). A satisfactory substitute is a slender bottle at least 6 in (150 mm) tall. The test tube requires a minimum of retardant and is a reasonably accurate way of collecting correct volume for enzyme treatment.

6. An all-metal, dial-type thermometer to measure slurry temperatures, range 25° to 125° F (−4° to 52° C). (Available from VWR Scientific Co.—catalog No. 61048-055). Or range 0° to 180° F (−18° to 82° C). Available from Fisher Scientific Co.—catalog No. 15-076B).

7. A clean pail or bucket for collecting the test sample.

8. A supply of Phos-Chek breaker enzyme for breaking viscosity of gum thickener.

CAUTION: **Managers shall insure security and safe storage of supply of enzyme. They shall instruct those who handle enzyme in necessary safety and sanitation procedures, with emphasis on the proper disposal of enzyme-treated samples and of spills of enzyme itself. (Also see later section.)**

9. A one-half teaspoon and a one teaspoon measure, preferably with long handles. (Available in housewares section of major stores.)

Selecting the Sample for Testing

Retardant testing shall be performed on a pailful of slurry that represents the average characteristics of the material *in the storage tanks.* Before testing:

1. Recirculate the product in the tanks, 24 hr after a major mixing operation for 10 min (minimum) and draw a sample from a recirculation line or pump.

2. During periods when little material is pumped, recirculate and sample at least every 7 days.

3. If significant deterioration is discovered in stored material, then (a) dip or draw a sample of bad material and hold for instructions, and (b) notify the manufacturer and your supervisor of the conditions.

4. During mixing operations, take control samples often enough to insure that measured values of tank samples, taken from material aged at least 24 hr, meet stated requirements.

5. Do not use as a sample slurry that has rested in lines, pumps, or hoses for long periods of time or that has been subjected to heating by the sun or to extended drying.

6. End-of-loading hose samples may be adequate, if enough stored material has been pumped out to insure that old slurry is completely purged from the piping.

Test Procedures

Test the samples in accordance with the following procedures:

Specific Weight

Specific weight measurement is optional, but may be useful in helping explain the reasons for variations from the standards. A small "postal" scale may be used to measure the net weight of a known volume of slurry. The following tabulation may be used to convert net weight to specific weight for a 1-qt (946.4-ml) sample.

Viscosity

Viscosity is measured with the Marsh funnel (large tip only), the measured 1-qt (946.4-ml) container, and a watch readable to 1 sec.

1. Let the sample rest in the bucket until excessive air bubbles have disappeared (about ½ hr). Tap the bucket gently on the ground to shake loose remaining bubbles.

2. Be sure the funnel is clean and dry and is held truly vertical.

3. Cover the funnel tip with a finger and pour the retardant ***through the screen*** until the fluid level ***exactly*** reaches the bottom of the screen.

Net weight	Specific weight lb/gal	g/cm^3	Net weight	Specific weight lb/gal	g/cm^3
2 lb ½ oz	8.1	0.97	2 lb 4½ oz	9.1	1.09
2 lb 1 oz	8.2	0.98	2 lb 5 oz	9.2	1.10
2 lb 1½ oz	8.4	1.01	2 lb 5½ oz	9.4	1.13
2 lb 2 oz	8.5	1.02	2 lb 6 oz	9.5	1.14
2 lb 2½ oz	8.6	1.03	2 lb 6½ oz	9.6	1.15
2 lb 3 oz	8.8	1.05	2 lb 7 oz	9.8	1.17
2 lb 3½ oz	8.9	1.07	2 lb 7½ oz	9.9	1.19
2 lb 4 oz	9.0	1.08	2 lb 8 oz	10.0	1.20

NOTE: If the weight of the 1-qt (946.4-ml) sample is outside the above range, convert the net weight to specific weight by taking the number of whole pounds, plus the ounces divided by 16, and multiplying this by 4; or 4 x (whole lb + oz/16).

Acceptable values for Phos-Chek XA retardant are 8.9 lb/gal (1.07 g/cm^3).

4. Measure the time (in minutes and seconds) it takes flow from the funnel orifice to fill the measuring container to the 1-qt (946.4-ml) mark. Use only the retardant originally contained in the funnel—***do not*** add more during the measuring process.

5. Use the dial-type thermometer to measure solution temperature. Record it. If a temperature correction table has been prepared, use it to determine the adjusted funnel time.

6. Using Research Note INT-205, look up the measured time in the left-hand side of the Marsh funnel time table. Read the proper column to the right to find viscosity in centipoise. The boxes indicate satisfactory operational use ranges. For Phos-Chek XA retardant the satisfactory range is 45 to 65 sec—or 1502 to 2067 cP (average is 52 sec or 1750 cP).

Salt Content

Salt content is measured with the hydrometer. The thickening agent in Phos-Chek XA retardant prevents direct readings, so non-viscous samples ***must*** be prepared. Viscosity is destroyed by action of an enzyme added to the sample.

CAUTION: **Never attempt to take hydrometer readings in thickened solutions. Laboratory tests demonstrate that the hydrometer will never reach a true value, and that there is no meaningful relationship of such thick solution readings to those obtained in non-viscous samples.**

To prepare an unthickened solution of Phos-Chek XA retardant and test for salt content:

1. Fill the 100-cm^3 test tube to within 1-in (2.54-cm) of the top.

2. Stir or agitate the solution while adding the proper measure of enzyme. Since the enzyme itself affects specific gravity, table 5 in Research Note INT-138 has correction factors built-in to compensate for that effect. The correction factors are based on the following proportions:

Slurry volume	Added enzyme
1 qt (946 ml, or cm^3)	4 level tsp (20 cm^3, or ml)
1 pt (473 ml)	2 level tsp (10 cm^3)
½ pt, or 1 cup (237 ml)	1 level tsp (5 cm^3)
¼ pt, or ½ cup (118 ml)	½ level tsp (2½ cm^3)
Full pyrex test tube (100 ml)	½ level tsp, less about 15% (2-1/8 cm^3)
Test tube full, less 1 in (84 to 90 ml)	½ level tsp, less 25% (1-7/8 cm^3)

CAUTION: **Use Phos-Chek breaker only in areas well removed from storage tanks. Thoroughly flush any spilled enzyme or sample containing breaker enzymes into regular sewage disposal systems. Very thoroughly clean all containers and instruments used with enzyme. Such items should not be stored nor used in areas close to storage tanks. Never return enzyme-treated material to tanks nor dump into mixing plant drainage systems.**

3. Securely cover end of the test tube and shake vigorously, then let it rest about 20 min. A half-filled 1-qt (946.4-ml) jar with a tight lid can also be used as a shaker to mix the enzyme. After adding 2 level teaspoons (10 cm^3) of enzyme and shaking, pour some into the 100-cm^3 test tube and start the rest period.

4. Use the dial-type thermometer to measure solution temperature. Record it.

5. Place the hydrometer in the solution and let it rest for about a minute before reading. Read and record specific gravity units. Be sure the bulb is fully and freely floating and no air bubbles are supporting it. It should return freely to a constant level after being disturbed. Readings are always in the form of 1.XXX, and observation to the nearest 0.001 is normal.

A correction to specific gravity may be needed if solution temperature varies significantly from 80° F (27° C). This correction is the same for all retardants and is as follows:

Solution temperature	Add to or subtract from hydrometer reading
98° to 102° F (37° to 39° C)	Add 0.004
93° to 97° F (34° to 36° C)	Add 0.003
88° to 92° F (31° to 33° C)	Add 0.002
83° to 87° F (28° to 30½° C)	Add 0.001
78° to 82° F (25½° to 28° C)	None
73° to 77° F (23° to 25° C)	Subtract 0.001
68° to 72° F (20° to 22° C)	Subtract 0.002
63° to 67° F (17° to 19° C)	Subtract 0.003
58° to 62° F (14° to 17° C)	Subtract 0.004
53° to 57° F (12° to 14° C)	Subtract 0.005
48° to 52° F (9° to 11° C)	Subtract 0.006

Using Research Note INT-138, look up the corrected specific gravity reading in the left-hand side of table 5. Read salt content or salt equivalency from the proper columns. If salt content is not within the indicated operational use range, the two right-hand columns show amounts of water or product needed for correction. The box indicates satisfactory operational use range. For Phos-Chek XA retardant, the acceptable range is 1.065 to 1.080 specific gravity units (average is 1.074).

Recommended Corrective Actions

The viscosity of Phos-Chek XA retardant solution is relatively independent of shear, and the final salt content and viscosity values are mostly depending on the ratio of product to water. Only a small amount of shear or mixing energy is necessary to dissolve the salt and uniformly disperse the gum thickener, with a satisfactory buildup of viscosity requiring only 10 to 20 min. If low salt values are observed, it is likely viscosity will also be low. Conversely, high salt is usually accompanied by high viscosity. Because Phos-Chek is usually mixed with a constant flow eductor, it is impractical to use viscosity as an immediate measure of retardant quality. Instead, the manager makes hydrometer readings directly in samples taken from the mixer outlet. If normal values for salt content are observed, then it is usually safe to assume that viscosity will eventually build to normal values.

1. If a water meter/Phos-Bin [10/] container system is not available, the mix coming from the eductor should be a

[10/] ®Phos-Bin, registered trademark of Monsanto Co., St. Louis, MO.

little on the rich side. This is because it is difficult to prevent some plain water from going into the tank at the start and the finish of mixing. If the adjustment for this dilution produces a rich tank mix, additional water can be added. Be sure recirculation time is long enough and vigorous enough to make the tank mix uniform.

A low salt/low viscosity mixture is harder to correct, because it may be very difficult to disperse the required additional dry material uniformly throughout the tank. Either a very rich mix must be added and recirculated, or the substandard mix must be run back through the eductor as additional product is added. Very few bases or stations have their plumbing arranged in a way that permits this last procedure. In some cases, this type of hookup may not be permitted because of the possibility of back-contamination of the water supply system.

2. If abnormal relationships still exist after corrective actions are taken, such as high salt/low viscosity or vice versa, other factors must be considered. For instance, viscosity of the mixed retardant can be affected by several conditions, such as temperature of the mix water, water hardness (specifically the type of ions in it), and the temperature of the stored retardant mix. A small amount of impurities may have a significant effect on viscosity and, in some cases, may cause a complete breakdown of thickener.

If the manager is trying to raise viscosity, the salt content should not be increased more than 10 percent above the average value—1.080 specific gravity at 80° F (27° C). If viscosity drops much below 1500 cps when the salt is at the upper limit, the manager should look for other problems, including a possible source of contamination, such as the following:

a. Water of a reduced quality or containing impurities. (Whether highly chlorinated water might be included in this category is currently under study.) Never use washdown water; it might contain gas, oil, brighteners, or zinc chromate (or other retardant formulations). The addition of Fire-Trol 100 retardant to Phos-Chek XA retardant may contaminate the Phos-Chek retardant and cause reduction of viscosity provided by the gum thickener.

b. Excessively low proportions of Phos-Chek XA retardant in water. This situation may provide ideal conditions for bacterial attack and would be typified by the solution remaining in the bottom of a tank (below the bottom of a side-mounted outlet) after initial washdown of the tank's interior. It is highly likely there will not be enough bactericide left to prevent bacterial growth on the remaining gum. Warm temperatures will accelerate bacterial growth, and creation of a highly contaminated culture or broth is likely. If fresh retardant is mixed with this culture, the large amount of bacteria and their associated enzyme may overwhelm even normally adequate levels of bactericide, so such residual water must never be used to mix new retardant.

This type of problem usually results in infection of the entire tank, and transfer system and is difficult to correct. The manufacturer needs to be consulted, and will usually assist with corrective action. The only satisfactory treatment may be thorough cleaning and flushing of the entire system, followed by a sterilization process *recommended by the manufacturer.*

c. A small amount of enzyme (Phos-Chek retardant breaker) can eventually destroy viscosity in an entire tank. Thus, enzyme (or retardant containing enzyme) must never be allowed to enter storage or mixing tanks. Enzymes may also come from natural sources and birds, animals, or other foreign objects that fall into the stored slurry must be removed promptly. *Never* let the storage tank be used as a garbage or trash can.

d. Before allowing an aircraft or engine (fire truck) to be off-loaded back into stored Phos-Chek retardant, check the condition of the retardant to be salvaged. If there is any suspicion of spoilage, either off-load into a separate holding tank or, if no tank is available, ask the pilot to abort the load when in the air or the engine operator to discard retardant in a safe area. *Never* transfer a load of Fire-Trol 100 retardant into stored Phos-Chek retardant mixes or transfer a load of Phos-Chek retardant into stored Fire-Trol slurry.

At most, a tanker load of retardant represents 20 percent of the cost of a full storage tank of Phos-Chek XA retardant. For an entire base this ratio may be 5 percent, or less. The risk of contamination and spoilage from off-loading must be weighed against those comparative costs.

3. If abnormal relationships of salt content and viscosity appear at a number of different locations, additional sampling may be required so that a body of data can be collected and studied for similar characteristics or trends. Only after naturally occurring factors are discounted and specific contamination sources or procedural problems are eliminated, will shortcomings in the manufacturers' formulation be considered. If problems of this type are suspected, request technical assistance from recognized agency specialists. The manufacturer should become involved and the field observations discussed with company representatives. Economic consequences of a problem affecting a significant number of mixing systems are potentially large and an aggressive search for solutions is required.

PHOS-CHEK 259 RETARDANT

Required Performance Characteristics

- Viscosity—200 centipoise (cP) maximum
- Salt content—15.0 percent minimum $(NH_4)_2HPO_4$ solution by weight.
- Specific weight—9.5 lb/gal (1.14 g/cm^3). maximum.
- pH: 5.5 to 8.0.

Expected Operational Values

- Viscosity—Marsh funnel time, 40 to 55 sec through the small tip—or 43 to 112 cP. Average = 52 sec or 100 cP.
- Salt content at 80° F (27° C)—1.090 to 1.100 specific gravity units—or 14.2 to 15.7 percent $(NH_4)_2HPO_4$ by weight. Average = 1.095 to 15.0 percent.
- Specific weight—9.1 lb/gal (1.09 g/cm^3). This corresponds to 1.60 lb (0.73 kg) of Phos-Chek 259 retardant added per gal (3.785 l) of water, which creates a solution with 1.46 lb (0.66 kg) of Phos-Chek 259 retardant per gal (3.786 l) of slurry.

Test Instruments and Measuring Devices

Have the following on hand:

1. Marsh funnel [11/] with a small orifice; 0.187 ± 0.002 in (0.475 + 0.005 cm) ID. [12/] (Available from Western Fire Equipment Co., 440 Valley Drive, Brisbane, CA 94005—catalog No. 12512

2. A container [11/] with a level mark, or volume determined, at precisely 1-qt (946.4-ml). A 1,000-ml (1.06-qt) Nalge polyproplene plastic graduated cylinder can be marked at the 1-qt (946.4-ml) level. (Available from VWR Scientific Co.—catalog No. 24776-144; or Fisher Scientific Co.—catalog No. 8-572G.)

3. A stopwatch or a watch with a sweep-second hand.[11/]

4. A hydrometer with a range of 1.060 to 1.130 specific gravity units, approximately 6 in (150 mm) long with 0.001-mm divisions. (Available from Fisher Scientific Co.—catalog No. 11-556G.)

5. A 100-cm^3 Pyrex No. 9820 test tube, 25 mm OD and 200-mm long, as a measuring container for the small hydrometers. (Available from Fisher Scientific Co.—

[11/] Optional—since the viscosity of Phos-Chek 259 retardant is usually *not* measured.

[12/] Deviations of more than 0.002 (0.005 cm) from the standard Marsh funnel tip size can cause substantial viscosity measurement errors. The listed vendor supplies Marsh funnels precisely reamed to the specific inside diameter (ID). A competent machinist can also manufacture a rod-shaped gauge to measure the orifice size on a go/no-go basis. Tolerances of ± 0.0005 in (0.0013 cm) are practical.

catalog No. 14-957N.) A satisfactory substitute is a slender bottle at least 6 in (150 mm) tall. The test tube requires a minimum of liquid and provides a quick, handy way to collect the right-size sample for the hydrometer.

6. An all-metal, dial-type thermometer to measure slurry temperatures, range 25° to 125° F (−4° to 52° C). (Available from VWR Scientific Co.—catalog No. 61048-055.) Or range 0° to 180° F (−18° to 82° C). (Available from Fisher Scientific Co.—catalog No. 15-076B.)

7. A clean pail or bucket for collecting the test sample.

Selecting the Sample for Testing

1. The principal retardant sample shall be taken from the mixer outlet.

2. The flow from the mixer should be sampled often enough to insure no long periods occur which have improper water/retardant mixtures.

3. If a storage tank is used, take occasional samples from it also.

Test Procedures

Test the samples in accordance with the following procedures:

Specific Weight

Specific weight measurement is optional, but may be useful in helping explain the reasons for variations from the standards. A small "postal" scale may be used to measure the net weight of a known volume of slurry. The following tabulation may be used to convert net weight to specific weight for a 1-qt (946.4-ml) sample.

Viscosity

Measurement of viscosity is optional; but if it is performed, required instruments are the Marsh funnel equipped with the small tip, the measured 1-qt (946.4-ml) container, and a watch readable to 1 sec.

1. Let the sample rest in the bucket a few minutes until excessive air bubbles have disappeared. Tap the bucket gently on the ground to shake loose remaining bubbles.

2. Be sure the funnel is clean and dry and is held truly vertical.

3. Cover the funnel tip with a finger and pour the retardant ***through the screen*** until the fluid level ***exactly*** reaches the bottom of the screen.

4. Measure the time (in minutes and seconds) it takes flow from the funnel orifice to fill the measuring container to the 1-qt (946.4-ml) mark. Use only the retardant originally contained in the funnel—***do not*** add more during the measuring process.

Net weight	Specific weight lb/gal	Specific weight g/cm^3	Net weight	Specific weight lb/gal	Specific weight g/cm^3
2 lb ½ oz	8.1	0.97	2 lb 4½ oz	9.1	1.09
2 lb 1 oz	8.2	0.98	2 lb 5 oz	9.2	1.10
2 lb 1½ oz	8.4	1.01	2 lb 5½ oz	9.4	1.13
2 lb 2 oz	8.5	1.02	2 lb 6 oz	9.5	1.14
2 lb 2½ oz	8.6	1.03	2 lb 6½ oz	9.6	1.15
2 lb 3 oz	8.8	1.05	2 lb 7 oz	9.8	1.17
2 lb 3½ oz	8.9	1.07	2 lb 7½ oz	9.9	1.19
2 lb 4 oz	9.0	1.08	2 lb 8 oz	10.0	1.20

NOTE: If the weight of the 1-qt (946.4-ml) sample is outside the above range, convert the net weight to specific weight by taking the number of whole pounds, plus the ounces divided by 16, and multiplying this by 4; or 4 x (whole lb + oz/16).

Acceptable values for Phos-Chek 259 retardant are 9.1 lb/gal (1.09 g/cm^3).

5. Use the dial-type thermometer to measure solution temperature. Record it. If a temperature correction table has been prepared, use it to determine the adjusted funnel time.

6. Using Research Note INT-205, look up the measured time in the left-hand side of the table. Read the proper column to the right to find viscosity in centipoise. The boxes indicate satisfactory operational use ranges. For Phos-Chek 259 retardant the satisfactory range is 40 to 55 sec—or 43 to 112 cP. (Average is 52 sec or 100 cP.)

Salt Content

Salt content is measured with the hydrometer. No special treatment of the solution is required.

1. Collect enough retardant to fill the 100-cm^3 test tube about three-quarters full.

2. Use the dial-type thermometer to measure solution temperature in the test tube. Record it.

3. Place the hydrometer in the solution, read specific gravity units and record. Be sure the bulb is fully and freely floating and no air bubbles are supporting it. Readings are always in the form of 1.XXX, and observation to the nearest 0.001 is normal.

A correction to specific gravity may be needed if solution temperature varies significantly from 80° F (27° C). This correction is the same for all retardants and is as follows:

Solution temperature	Add to or subtract from hydrometer reading
98° to 102° F (37° to 39° C)	Add 0.004
93° to 97° F (34° to 36° C)	Add 0.003
88° to 92° F (31° to 33° C)	Add 0.002
83° to 87° F (28° to 30½° C)	Add 0.001
78° to 82° F (25½° to 28° C)	None
73° to 77° F (23° to 25° C)	Subtract 0.001
68° to 72° F (20° to 22° C)	Subtract 0.002
63° to 67° F (17° to 19° C)	Subtract 0.003
58° to 62° F (14° to 17° C)	Subtract 0.004
53° to 57° F (12° to 14° C)	Subtract 0.005
48° to 52° F (9° to 11° C)	Subtract 0.006

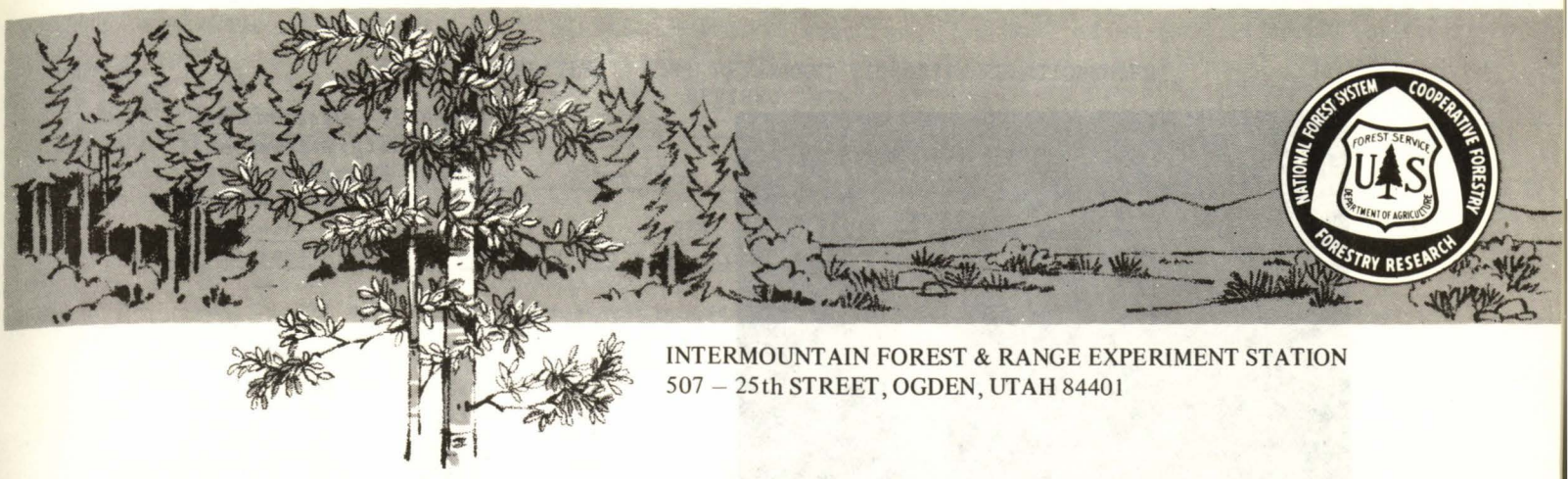
Using Research Note INT-138, look up the corrected specific gravity reading in the left-hand side of table 4. Read salt content or salt equivalency from the proper columns. If salt content is not of average value, the two right-hand columns show amounts of water or product needed for correction. The box indicates satisfactory operational use range. For Phos-Chek 259 retardant the acceptable range is 1.090 to 1.100 specific gravity units (average is 1.095).

Recommended Corrective Actions

The quality of Phos-Chek 259 retardant solution is almost exclusively a function of salt content. Simply increase or decrease the product-to-water ratio to produce normal salt values.

"REVISED MARSH FUNNEL CALIBRATIONS FOR MEASURING FIRE RETARDANT VISCOSITY"

RESEARCH NOTE INT-205
1976



INTERMOUNTAIN FOREST & RANGE EXPERIMENT STATION
507 – 25th STREET, OGDEN, UTAH 84401

USDA Forest Service
Research Note INT-205
1976

REVISED MARSH FUNNEL CALIBRATIONS FOR MEASURING FIRE RETARDANT VISCOSITY

Charles W. George and Cecilia W. Johnson[1]

ABSTRACT

Updates data (Research Note INT-91) for measuring viscosity of fire retardants in the field by means of the Marsh Funnel. New data cover Tenogum and gum-thickened Fire-Trol 931. Data for Gelgard (no longer available) have been dropped.

OXFORD: 432.3, 843.1
KEYWORDS: aerial fire suppression, chemical fire retardants, viscosity testing, retardant quality control

In 1966, the Marsh Funnel was first modified so that the viscosity of forest fire retardants could be quickly and inexpensively determined in the field (George and Hardy 1966, 1967).

Because of changes in the retardants and formulations, procedures for measuring viscosity were revised in 1969 (George and Hardy 1969). Since then, retardants or their formulations have continued to change. This research note presents recent revisions in calibration and test procedures.

The calibration data were obtained by comparing viscosities from the Brookfield Viscometer with the flow-through times for the Marsh Funnel; thus, "Marsh-Funnel time" serves as an inexpensive method for determining viscosity (fig. 1).

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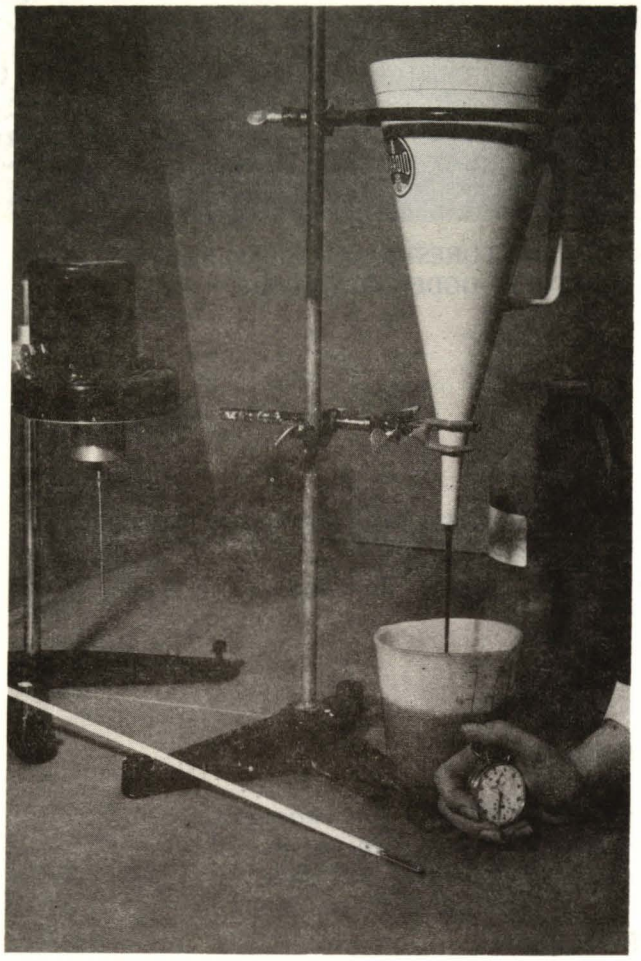

Figure 1.--Determining viscosity with a Marsh Funnel.

INSTRUCTIONS FOR USING THE MARSH FUNNEL

1. Place the appropriate tip in the Marsh Funnel.
2. Use only fresh samples that have stabilized; i.e., excessive air bubbles have disappeared and complete hydration has occurred (approximately 1/2 to 1 hour after mixing).
3. Cover the funnel tip with a finger and pour the retardant *through* the screen into a clean, dry, upright funnel until the fluid level *exactly* reaches the bottom of the screen.
4. Measure the time in minutes and seconds for 1 quart (946 ml) of retardant to flow through the funnel--the funnel holds approximately 2 quarts (1,892 ml).
5. Look up measured time on left-hand side of table. Read proper column to the right to find viscosity in centipoise.

NOTE:

1. Keep in mind that time elapsed since agitation and retardant temperature influence viscosity. The viscosity found in the table will apply to the retardant only at the time and temperature at which the sample is tested.
2. For the samples tested in the laboratory, the Marsh Funnel method gave viscosities within 5 percent of the Brookfield method.
3. Numbers included within the boxes indicate the normal use ranges.

MARSH FUNNEL TIME - FIRE RETARDANT VISCOSITY RELATIONSHIPS[1]
REVISED 1976

Time for 1 qt (946 ml) to flow thru funnel[2] (min:sec)	Tenogum	Phos-Chek		Fire-Trol			
		XA	259	100		931 gum-thickened[4]	931 concentrate
	lg tip[3]	lg tip	sm tip[3]	lg tip	sm tip	lg tip	lg tip
	Centipoise						
0:10							
:15	310			930		147	
:20	532	557		1530		473	
:25	703	767		1900		727	
:30	843	966	5	2140		934	
:35	962	1155	20	2330		1109	
:40	1065	1334	43	2480	920	1260	
:45	1155	1502	66	2590	1110	1394	
:50	1236	1659	89	2680	1250	1514	
:55	1310	1806	112	2750	1370	1622	
1:00	1377	1942	136	2800	1460	1721	1900
:05	1438	2067	159	2840	1541	1811	
:10	1495	2183	182	2880	1610	1896	
:15	1548	2287	205	2900	1670	1974	
:20	1598	2381	228	2920	1720	2047	
:25	1645	2465	251	2930	1770	2116	
:30	1689	2538	274	2940	1810	2181	
:35	1730		297	2950	1840	2242	
:40	1770		320	2960	1870	2300	
:45	1807		343		1900	2356	
:50	1843		367		1940	2409	
:55	1877		390		1960	2459	
2:00	1910		413			2507	2200
:15	2000					2641	
:30	2081					2761	
:45	2155					2869	
3:00	2222					2968	2500
:15	2283					3059	
:30	2340						
:45	2393						
4:00	2443						2800
:15	2490						
:30	2534						
:45	2575						
5:00	2615						3100
6:00							3400
8:00							4000
10:00							4600
12:00							5200

[1] Viscosities by Brookfield Model LVF, at 60 r/min, spindle 4 (for viscosities of more than 500 cP) or spindle 2 (for viscosities from 1-500 cP); at a temperature of 65-75° F, higher temperatures may give false low viscosities, lower temperatures may give false high viscosities.

[2] Funnel must be full to screen before testing begins.

[3] Large tip diameter should be 0.269 ±0.002 inch; small tip inside diameter should be 0.187 ±0.002 inch.

[4] Viscosity is dependent upon age of gum, storage time and conditions, and degree of agitation prior to use.

The revised table published here includes only products currently being used. New products (since the last revision) are Fire-Trol 931 (LC), gum-thickened Fire-Trol 931, and Tenogum. The formulation of Phos-Chek XA (replacement for 202 or 202 XA) has been altered, although no change in the calibration has been necessary. The viscosity of unthickened, diluted Fire-Trol 931 does not change significantly with the change in dilution rate, and its low viscosity limits the usefulness of Marsh Funnel measurements. (Fire-Trol 931 diluted with water at the rate of four parts water to one part concentrate yields a solution with a Brookfield viscosity of approximately 70 centipoise, or 12 Marsh-Funnel seconds.)

The Marsh Funnel packet is still available. It contains the table, instructions for converting a Marsh Funnel, and a list of commercial sources. Separate tables and the packet can be ordered from the Northern Forest Fire Laboratory, Intermountain Forest and Range Experiment Station, Drawer G, Missoula, Montana 59801.

PUBLICATIONS CITED

George, Charles W., and Charles E. Hardy.
1966. Fire retardant viscosity measured by modified Marsh Funnel. USDA For. Serv. Res. Note INT-41, 4 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

George, Charles W., and Charles E. Hardy.
1967. Fire retardant viscosity measured by modified Marsh Funnel. USDA For. Serv. Fire Control Notes 28(4):13-14.

George, Charles W., and Charles E. Hardy.
1969. Revised Marsh Funnel table for measuring viscosity of fire retardant. USDA For. Serv. Res. Note INT-91, 2 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

APPENDIX II

"RETARDANT SALT CONCENTRATION MEASURED IN THE FIELD"

RESEARCH NOTE INT-138
JUNE 1971

Research Note

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE

INTERMOUNTAIN FOREST & RANGE EXPERIMENT STATION
OGDEN, UTAH 84401

USDA Forest Service
Research Note INT-138

June 1971

RETARDANT SALT CONCENTRATION MEASURED IN THE FIELD

Charles W. George[1]

ABSTRACT

The effectiveness of long-term fire retardants is related to the concentration of the active fire-inhibiting salt. Quality control at each retardant base is necessary to assure that maximum effectiveness is obtained. This note describes simple field methods for determining the salt content of retardant solutions now in use.

Previous studies have indicated that the effectiveness of long-term fire retardants is related to the amount and type of active chemical salt present in a given fuel and fire situation. To assure that the desired salt concentration and effectiveness is obtained, retardant base personnel must have the capability of monitoring the salt content.

Previous methods of monitoring retardant quality have included viscosity and density measurements.[2] [3] Although viscosity is important because of its relation to aerial drop characteristics, it is not necessarily related to salt content. Viscosity has an important effect, however, on the amount of salt retained by aerial fuels. The viscosity of a retardant depends on the type and amount of thickening agent, water hardness, temperature, and method of mixing (shear, etc.). The density and specific

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[1]Research Forester, stationed at the Northern Forest Fire Laboratory, Missoula, Montana.

[2]Charles W. George and Charles E. Hardy. Revised Marsh funnel table for measuring viscosity of fire retardants. USDA Forest Serv. Res. Note INT-91, 2 p., 1969.

[3]National Fire Protection Association. Chemicals for forest fire fighting. Ed. 2, p. 75-87. Boston: National Fire Protection Association, 1967.

gravity[4] are related to the concentration of salt and other ingredients in solution. The retardant salt is the primary ingredient in fire retardants and its concentration can be correlated to the specific gravity if the manufacturer's formulation remains constant. Past salt analyses show the manufacturer's formulation to remain acceptably constant if the samples are of an adequate size.

AVAILABLE MEASURING METHODS

Methods for measuring the density and specific gravity of retardants have included use of the Baroid mud balance[5] and the hydrometer. The mud balance consists of a graduated arm that has a constant volume cup attached to one end and an adjustable counterweight on the other end. The arm is scaled for both specific gravity and density. The hydrometer is a simple floating instrument which measures gravimetrically the buoyancy exerted on a glass-enclosed body of definite volume immersed in the liquid. The instrument is graduated in units of specific gravity.

Direct measurements of the specific gravity and density of retardants with the hydrometer and mud balance are complicated by the presence of thickening agents. These agents decrease the accuracy of such measurements for several reasons:

1. Viscous materials restrict free movement of the hydrometer and provide a poor meniscus. (The meniscus is the curved liquid surface in contact with the hydrometer.)

2. The volume of some types of thickening agents (especially clays) is dependent on the amount of hydration and mixing. Thus, a change in the volume and density may be due to changes in physical properties of the solution rather than a change in its salt content.

3. Air bubbles are common in freshly agitated retardant samples and cause errors in weight-volume measurements taken with the mud balance; also, bubbles affect the buoyancy exerted on a hydrometer.

FIELD PROCEDURES

The above problems can be solved by breaking down the thickening agent before measuring the specific gravity and estimating the salt content of presently used fire retardants. Retardants[6] presently being used and their major physical-chemical properties are given in table 1. The viscosity of highly viscous gum-thickened retardants such as Phos-Chek® 202 and 202XA can be reduced prior to determining the specific gravity by addition of a chemical known to break polymeric chains. A procedure to remove the clay from clay-thickened products, such as Fire-Trol 100, must be used because clay interferes with free hydrometer movement. Because of the nature of

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[4]The density is the weight per unit volume. The specific gravity of a liquid is the ratio of its density to that of water at 4° C. and for practical purposes is equivalent to its density in grams per cubic centimeter.

[5]The Baroid mud balance is manufactured by the Baroid Division, National Lead Co., P.O. Box 1675, Houston, Tex. The use of firm names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product to the exclusion of others which may be suitable.

[6]The retardants presently being used and mentioned in this paper were formally submitted and evaluated under USDA Forest Service Interim Specification 5100-00301, Specification for Retardant, Forest Fire, Dry Chemical and Fixed-Wing Aircraft Application; or USDA Forest Service Interim Specification 5100-00302, Specification for Retardant, Forest Fire, Liquid Chemical, Unthickened for Aircraft or Ground Application.

Table 1.--*Physical-chemical characteristics of presently used fire retardants*

Retardant[1]	Recommended use level lbs./gal. of water or dilution rate[2]	Viscosity[3]	Density of slurry	Percent DAP $(NH_4)_2HPO_4$ or DAP equivalent	Percent ammonium sulfate $(NH_4)_2SO_4$	Percent[4] P_2O_5 equivalent	Specific gravity of slurry or filtrate (using analyses procedures)
		Centipoise	*Lbs./gal.*				
Phos-Chek 202	1.14	800-1500	8.9	10.6		5.7	1.072
Phos-Chek 202XA	1.14	1500-2000	8.9	10.6		5.7	1.072
Phos-Chek 259	1.60	50-100	9.1	15.0		8.1	1.095
Fire-Trol 930	4:1	5-60	9.1	16.2		8.7	1.096
Fire-Trol 931	4:1	30-120	9.2	15.4		8.3	1.092
Fire-Trol 934	4:1	5-60	9.1	15.8		8.5	1.094
Fire-Trol 100	2.78	1500-2500	9.4		15.6		1.101
Pyro (11-37-0)	5:1	50-100	9.0	14.9		8.0	1.078

[1]Phos-Chek is a product of Monsanto, St. Louis, Missouri. Fire-Trol is a product of Arizona Agrochemical Co., Phoenix, Arizona. Fire-Trol 930 is composed of Allied Chemical Co.'s Arcadian Poly-N 10-34-0 and a corrosion inhibitor. Fire-Trol 931 is composed of Allied Chemical Co.'s Arcadian Poly-N 10-34-0, clay, coloring, and corrosion inhibitor. Fire-Trol 934 is composed of Allied Chemical Co.'s Arcadian Poly-N 10-34-0, wetting agent, and corrosion inhibitor. Pyro (11-37-0) is manufactured by Tennessee Valley Authority, Muscle Shoals, Alabama, and contains 1.5 percent $Na_2Cr_2O_7$ corrosion inhibitor.

[2]The dilution rate is by volume; a dilution rate of 4:1 means 4 gallons of water are added to 1 gallon of liquid concentrate to provide approximately 5 gallons of retardant solution.

[3]Viscosities by Brookfield viscometer Model LVF, at 60 r.p.m., spindle number 2 or 4.

[4]The P_2O_5 equivalent is determined from the percent by weight DAP using the formula: Percent P_2O_5 = percent DAP ÷ 1.86. The equivalent P_2O_5 content is not necessarily the same as the *active* salt content (because of other retardant ingredients) although the P_2O_5 equivalent can be used for quality control.

clay, it can be removed more readily by filtration than by use of flocculation agents. The specific gravity of products that have no thickening agent (Pyro, Fire-Trol 930 and 934) or gum-thickened products with only slight viscosity (Phos-Chek 259) can be determined without any special preparatory procedures.

Thus, because of the types of thickening agents, three different procedures are necessary for determining the salt content of present fire retardants. These procedures were developed by trial and error after excluding the possibility of devising a simple field method based on chemical analyses and are given in the three following sections.

1. Procedure for unthickened or thin, gum-thickened retardants--Pyro (TVA 11-37-0), Fire-Trol 930 and 934, and Phos-Chek 259.

2. Procedure for thick, gum-thickened retardants--Phos-Chek 202 and 202XA.

3. Procedure for clay-thickened retardants--Fire-Trol 100 and 931. Fire-Trol 931 is a clay-thickened, liquid concentrate which when diluted falls in the unthickened retardant category.

Following development of satisfactory field procedures, the specific gravity and the retardant salt content were correlated. For calibration purposes, a minimum of 10 samples of each retardant was prepared, varying only the mixing ratio or use level. This provided 10 different salt contents and specific gravities. The specific gravity was read while temperature of the solution was at 80±2° F. Using a computer method for linear regression, an equation was determined that fitted these points best in the least squares sense. The equation for salt content as a function of specific gravity was then evaluated and a table compiled. A correction factor was then calculated for retardant salt contents which deviated from the recommended salt content. *This use-level correction factor per 100 gallons of retardant solution will enable field personnel to adjust an improper salt content. (See the table for each product: tables 2, 3, 4, 5, 6, and 7).* Selection of a method for correction of an improper salt content will depend on the type of retardant, the mixing equipment, and the existing plumbing.

Under field conditions the specific gravity of a retardant solution or slurry may be measured at a temperature other than 80±2° F.; therefore, it was necessary to determine the effect of temperature on specific gravity. Samples of each retardant with the recommended salt content were prepared and the specific gravity measured at 10° intervals between 40° and 110° F. The effect of temperature on the specific gravity was found to be the same for all retardants, for all practical purposes. The average change in specific gravity was found to be approximately 0.002 specific gravity units per 10° F. Thus, if the specific gravity of the retardant solution cannot be measured near 80° F., the following rule of thumb should be applied: *For every 10° F. the retardant solution is below 80° F., subtract 0.002 from the hydrometer reading; or for every 10° F. the retardant solution is above 80° F., add 0.002 to the hydrometer reading.*

PROCEDURES FOR SPECIFIC PRODUCTS[7]

PROCEDURE FOR UNTHICKENED OR THIN, GUM-THICKENED RETARDANTS

Pyro (TVA 11-37-0), Fire-Trol 930 and 934, and Phos-Chek 259

The retardants are either unthickened, or thickened only slightly, and regular hydrometer readings can be taken.

1. Take a freshly agitated quart sample of the solution or slurry to be analyzed for salt content. (This sample will also be suitable for viscosity measurement, using the Brookfield viscometer or the Marsh funnel.) Allow the sample to reach room temperature (approximately 80° F.).

2. After all entrapped air bubbles are allowed to escape, measure the specific gravity of the solution using a high precision hydrometer (Sargent-Welch S-41885G for specific gravity 1.060 - 1.130 by 0.001 divisions). Be sure to let the hydrometer settle in the solution for 3 to 5 minutes before reading.

3. Record the specific gravity to the nearest 0.001 and extrapolate from tables 2, 3, and 4 the percent by weight, P_2O_5 equivalent, or DAP [$(NH_4)_2HPO_4$] equivalent. (If the active chemical used in the retardant formulation was DAP, the percent DAP rather than P_2O_5 equivalent will appear in the first column following the specific gravity.)

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[7]The equipment recommended for use in these field procedures is given on page 14 following the procedures.

Table 2.--*Pyro 11-37-0 salt content as related to specific gravity*[1]

Measured specific gravity of retardant solution	Percent P_2O_5 equivalent (by weight)	Percent DAP $(NH_4)_2HPO_4$ (by weight)	Correction[2] required per 100 gallons of retardant solution	
			Concentrate	Water
			Gals.	
1.045	4.9	9.1	8.1	
1.050	5.4	10.0	6.8	
1.055	5.8	10.8	5.8	
1.060	6.3	11.7	4.5	
1.065	6.8	12.6	3.2	
[3]				
1.070	7.3	13.6	1.9	
1.075	7.7	14.3	.8	
1.078	8.0	14.9	0	0
1.080	8.2	15.3		3
1.085	8.7	16.2		10
1.090	9.2	17.1		16
1.095	9.6	17.9		22
1.100	10.1	18.8		29
1.105	10.6	19.7		36
1.110	11.1	20.6		43
1.115	11.5	21.4		49
1.120	12.0	22.3		56
1.125	12.4	23.1		62
1.130	13.0	24.2		71
1.135	13.4	24.9		77
	Expanded Scale			
1.150	14.9	27.7		99
1.175	17.2	32.0		135
1.200	19.6	36.5		174
1.225	22.0	40.9		214
1.250	24.3	45.2		255

[1]The recommended use level for Pyro 11-37-0 is 5 parts water to 1 part concentrate by volume. An adequate specific gravity and salt content corresponding to this use level is outlined within the table. Values for salt content were determined from the equation: Percent P_2O_5 equivalent = 95.05 specific gravity - 94.44.

[2]Correction needed to obtain the recommended salt content.

[3]The lined area indicates a satisfactory salt content exists and no adjustment is needed. The satisfactory salt content was determined by allowing approximately a 10-percent deviation above and below the recommended salt content.

Table 3.--*Fire-Trol 930 and 934 salt content as related to specific gravity*[1]

Measured specific gravity of filtrate	Percent P_2O_5 equivalent (by weight)	Percent DAP $(NH_4)_2HPO_4$ (by weight)	Correction[2] required per 100 gallons of retardant solution	
			Concentrate	Water
			Gals.	
1.060	5.6	10.4	10.2	
1.065	6.0	11.2	9.3	
1.070	6.5	12.1	6.5	
1.075	6.9	12.8	5.3	
1.080	7.3	13.6	4.1	
[3] 1.085	7.7	14.3	2.8	
1.090	8.2	15.3	1.3	
1.095	8.6	16.0	0	0
1.100	9.0	16.7		5
1.105	9.5	17.7		12
1.110	9.9	18.4		17
1.115	10.3	19.2		23
1.200	10.8	20.1		29
1.125	11.2	20.8		34
1.130	11.6	21.6		39
1.135	12.0	22.3		45
1.140	12.5	23.3		52
1.145	12.9	24.0		57
1.150	13.3	24.7		63
1.155	13.8	25.7		70
	Expanded Scale			
1.175	15.5	28.8		94
1.200	17.6	32.7		126
1.225	19.8	36.8		160
1.250	21.9	40.7		193

[1]The recommended use level for Fire-Trol 930 and Fire-Trol 934 is 4 parts water to 1 part concentrate by volume. An adequate specific gravity and salt content corresponding to this use level is outlined within the table. Values for salt content were determined from the equation: Percent P_2O_5 equivalent = 85.92 specific gravity - 82.09.

[2]Correction needed to obtain the recommended salt content.

[3]The lined area indicates a satisfactory salt content exists and no adjustment is needed. The satisfactory salt content was determined by allowing approximately a 10-percent deviation above and below the recommended salt content.

Table 4.--*Phos-Chek 259 salt content as related to specific gravity*[1]

Measured specific gravity of retardant solution	Percent DAP $(NH_4)_2HPO_4$ (by weight)	Percent P_2O_5 equivalent (by weight)	Correction[2] required per 100 gallons of retardant solution	
			Retardant	Water
			Lbs.	*Gals.*
1.050	8.2	4.4	76	
1.055	9.0	4.8	68	
1.060	9.7	5.2	60	
1.065	10.5	5.6	51	
1.070	11.2	6.0	43	
1.075	12.0	6.4	34	
1.080	12.7	6.8	27	
1.085	13.5	7.3	17	
[3] 1.090	14.2	7.7	9	
1.095	15.0	8.1	0	0
1.100	15.7	8.4		6
1.105	16.5	8.9		11
1.110	17.3	9.3		17
1.115	18.0	9.7		22
1.120	18.8	10.1		28
1.125	19.5	10.5		34
1.130	20.3	10.9		40
1.135	21.0	11.3		45
1.140	21.8	11.7		52
1.145	22.5	12.1		57
1.150	23.3	12.5		64

[1]The recommended use level for Phos-Chek 259 is 1.60 lbs./gal. of water. An adequate specific gravity and salt content corresponding to this use level is outlined within the table. Values for salt content were determined from the equation: Percent DAP = 150.72 specific gravity - 150.05.

[2]Correction needed to obtain the recommended salt content.

[3]The lined area indicates a satisfactory salt content exists and no adjustment is needed. The satisfactory salt content was determined by allowing approximately a 10-percent deviation above and below the recommended salt content.

PROCEDURE FOR THICK, GUM-THICKENED RETARDANTS

Phos-Chek 202 and 202XA[8]

1. Take a freshly agitated sample of the Phos-Chek® slurry to be analyzed for salt content (this sample will also be suitable for viscosity measurement, using either the Brookfield viscometer or the Marsh funnel). Allow the sample to reach room temperature (approximately 80° F.).

2. Using this sample, fill a quart jar one-half full. Then, using a teaspoon measure, *add two level teaspoon measures* (5 grams) of Phos-Chek® Breaker[9] to the sample. *NOTE: It is important that exactly the correct amount of Phos-Chek® Breaker be added.*

3. Shake vigorously for at least 30 seconds and loosen the lid to relieve air pressure and allow entrapped air bubbles to escape.

4. Allow the material to sit for 10 minutes.

5. Pour the material into a hydrometer cylinder and allow it to reach room temperature (approximately 80° F.). A 32 by 200 mm. test tube will suffice.

6. After allowing the material to sit for an additional 10 minutes (20 minutes from the time the enzyme was added), measure the specific gravity of the solution using a high precision hydrometer (Sargent-Welch S-41885G for specific gravity 1.060 - 1.130 by 0.001 divisions). Allow the hydrometer to settle in the solution for at least 1 minute before reading. *Do not allow any solution containing Phos-Chek® Breaker to be returned to the storage tank since a small amount can cause gradual reduction in viscosity of the entire tank.*

7. After recording the specific gravity to the nearest 0.001, extrapolate from table 5 the percent by weight DAP $[(NH_4)_2HPO_4]$ or P_2O_5 equivalent.

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[8]The procedure used for Phos-Chek 202 and 202XA is a modification of a method proposed by H. L. Vandersall and G. F. Snow, Monsanto Co., 1971.

[9]Phos-Chek® Breaker is a cellulase enzyme supplied by the Monsanto Co. Phos-Chek® Breaker packaged for fire retardant salt analysis can be obtained from the Northern Forest Fire Laboratory, Drawer G, Missoula, Montana 59801; or Monsanto Co., 810 East Main St., Ontario, California 91761.

Table 5.--*Phos-Chek 202 and 202XA salt content as related to specific gravity*[1]

Measured specific gravity of retardant solution	Percent DAP $(NH_4)_2HPO_4$ (by weight)	Percent P_2O_5 equivalent (by weight)	Correction[2] required per 100 gallons of retardant solution	
			Retardant	Water
			Lbs.	*Gals.*
1.030	4.0	2.2	72	
1.035	4.7	2.5	65	
1.040	5.5	3.0	56	
1.045	6.2	3.3	49	
1.050	7.0	3.8	40	
1.055	7.8	4.2	31	
1.060	8.5	4.6	24	
1.065	9.3	5.0	15	
1.070	10.0	5.4	7	
1.074	10.6	5.7	0	0
1.075	10.8	5.8		2
1.080	11.5	6.2		9
1.085	12.3	6.6		17
1.090	13.0	7.0		24
1.095	13.8	7.4		33
1.100	14.6	7.8		41
1.105	15.4	8.3		50
1.110	16.1	8.7		57
1.115	16.9	9.1		66
1.120	17.6	9.5		73

[3]

[1]The recommended use level for Phos-Chek 202 and 202XA is 1.14 lbs./gal. of water. An adequate specific gravity and salt content corresponding to this use level is outlined within the table. Values for salt content were determined from the equation: Percent DAP = 151.83 specific gravity - 152.42.

[2]Correction needed to obtain the recommended salt content.

[3]The lined area indicates a satisfactory salt content exists and no adjustment is needed. The satisfactory salt content was determined by allowing approximately a 10-percent deviation above and below the recommended salt content.

PROCEDURE FOR CLAY-THICKENED RETARDANTS

Fire-Trol 100 and 931

1. Take a freshly agitated 1- to $1\frac{1}{2}$-quart sample of the Fire-Trol slurry to be analyzed for salt content. (This sample will also be suitable for viscosity measurement using the Brookfield viscometer or the Marsh funnel.)

2. Place the sample in an 8-inch funnel containing a rapid and fairly retentive filter paper (Sargent-Welch S-32915L general purpose filter paper). Collect 80 to 100 ml. of the filtrate. Fire-Trol 100 samples will require about 30 minutes depending partially on the viscosity. Fire-Trol 931 samples will require about 10 minutes.

3. Place the filtrate in a hydrometer cylinder and allow it to reach room temperature (approximately 80° F.). A 32 by 200 mm. test tube will suffice.

4. Measure the specific gravity of the solution using a high precision hydrometer (Sargent-Welch S-41885G for specific gravity 1.060 - 1.130 by 0.001 divisions). Allow the hydrometer to settle in the solution for 1/2 to 1 minute before reading.

5. Record the specific gravity to the nearest 0.001 and extrapolate from tables 6 and 7 the percent by weight ammonium sulfate $[(NH_4)_2SO_4]$, P_2O_5 equivalent, or DAP $[(NH_4)_2HPO_4]$ equivalent, depending on type of retardant.

Table 6.--*Fire-Trol 100 salt content as related to specific gravity*[1]

Measured specific gravity of filtrate	Percent $(NH_4)_2SO_4$ by weight	Correction[2] required per 100 gallons of retardant solution	
		Retardant	Water
		Lbs.	*Gals.*
1.045	7.3	154	
1.050	8.1	140	
1.055	8.8	127	
1.060	9.6	114	
1.065	10.3	100	
1.070	11.0	86	
1.075	11.8	73	
1.080	12.5	59	
1.085	13.3	45	
1.090	14.0	31	
[3] 1.095	14.8	16	
1.100	15.5	2	
1.101	15.6	0	0
1.105	16.2		4
1.110	17.0		10
1.115	17.7		15
1.120	18.5		21
1.125	19.2		26
1.130	20.0		32
1.135	20.7		37
1.140	21.4		43
1.145	22.2		48
1.150	22.9		54
1.155	23.7		60
1.160	24.4		65

[1]The recommended use level for Fire-Trol 100 is 2.78 lbs./gal. of water. An adequate specific gravity and salt content corresponding to this use level is outlined within the table. Values for salt content were determined from the equation: Percent AS = 148.40 specific gravity - 147.74.

[2]Correction needed to obtain the recommended salt content.

[3]The lined area indicates a satisfactory salt content exists and no adjustment is needed. The satisfactory salt content was determined by allowing approximately a 10-percent deviation above and below the recommended salt content.

Table 7.--Fire-Trol 931[1] salt content as related to specific gravity

Dilution rate[2]	Measured specific gravity of filtrate	Percent P_2O_5 equivalent (by weight)	Percent DAP $(NH_4)_2HPO_4$ (by weight)	Correction[3] required per 100 gal of retardant solution	
				Concentrate	Water
				-Gallons-	
20:1	1.020	2.2	4.1	15.1	
15:1	1.028	2.8	5.2	13.8	
10:1	1.043	4.1	7.6	10.8	
9:1	1.047	4.4	8.2	10.1	
8:1	1.053	4.9	9.1	8.9	
7:1	1.060	5.5	10.2	7.5	
	1.065	5.9	11.0	6.5	
6:1	1.069	6.2	11.6	5.8	
	1.070	6.3	11.8	5.5	
	1.075	6.7	12.5	4.6	
5:1	1.080	7.2	13.3	3.3	
	1.085	7.5	14.1	2.6	
[4]	1.090	8.0	14.9	1.3	
	1.095	8.4	15.6	.3	
4:1	1.096	8.5	15.8	0	0
	1.100	8.8	16.4		3.9
	1.105	9.2	17.2		9.1
	1.110	9.6	17.9		14.4
	1.115	10.1	18.7		21.0
3:1	1.119	10.4	19.3		25.0
	1.125	10.9	20.3		31.8
	1.130	11.3	21.0		37.3
	1.135	11.7	21.8		42.8
	1.140	12.1	22.6		48.3
	1.145	12.5	23.3		53.9
	1.150	13.0	24.1		60.9
2:1	1.155	13.4	24.9		66.7
		EXPANDED SCALE			
	1.175	15.0	28.0		89.9
1:1	1.221	18.8	35.1		148.1
	1.225	19.2	35.7		154.4
	1.250	21.3	39.5		188.4

[1] Fire-Trol 931 is a general identification which includes the following: Fire-Trol 931-L (Allied 10-34-0), Fire-Trol 931-N (Cominco 10-34-0), and Fire-Trol 931-P (Simplot 10-34-0).

[2] Ratio of volume of water added to volume of concentrate.

[3] Correction needed to obtain the recommended salt content.

[4] The recommended use level for Fire-Trol 931 is four parts water to one part concentrate (by volume). A satisfactory specific gravity and salt content corresponding to this use level is outlined within the table. The satisfactory salt content was determined by allowing approximately a 10 percent deviation above and below the recommended salt content. Values for salt content were determined from the equation: Percent P_2O_5 equivalent = 83.02 specific gravity - 82.51.

EQUIPMENT

THE FOLLOWING EQUIPMENT RECOMMENDED FOR USE IN FIELD PROCEDURES[10]

1. *Procedure for unthickened or thin, gum-thickened retardants*

   Pyro (TVA 11-37-0), Fire-Trol 930 and 934, and Phos-Chek 259

   A. Quart jar or plastic bottle (S-8416, 32-ounce; 50 cents each).

   B. Hydrometer[11] (S-41885G 1.060 to 1.130 by 0.001 divisions; $3.75 each).

2. *Procedure for viscous, gum-thickened retardants*

   Phos-Chek 202 and 202XA

   A. Quart jar or plastic bottle (S-8416, 32-ounce; 50 cents each).

   B. Measuring teaspoon (obtained from hardware store).

   C. Hydrometer[11] (S-41885G 1.060 to 1.130 by 0.001 divisions; $3.75 each).

   D. Phos-Chek® Breaker, a cellulase compound, can be obtained at no cost from the Northern Forest Fire Laboratory, Drawer G, Missoula, Montana 59801; or the Monsanto Company, 810 East Main Street, Ontario, California 91761.

3. *Procedure for clay-thickened products*

   Fire-Trol 100 and 931

   A. Funnel (S-35433F, 8-inch diameter, short stem; $2.75 each).

   B. Filter paper (S-32915L No. 500, 40-cm. diameter; $3.62 per package of 100).

   C. Test tube (S-79540W 32 by 200 mm.; 48 cents each).

   D. Hydrometer[11] (S-41855G 1.060 to 1.130 by 0.001 divisions; $3.75 each).

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[10]The equipment used to prepare the tables was obtained from Sargent-Welch, 4040 Dahlia, Denver, Colorado 80207, telephone 303-399-8220. The numbers refer to Sargent Catalog 115 numbers. Field use of similar equipment would help insure reliable results.

[11]For specific gravity measurements outside the normal range 1.060 to 1.130, an appropriate hydrometer may be obtained ($3.75 each):

S-41885F 1.000 to 1.070 by 0.001 divisions
S-41885H 1.120 to 1.190 by 0.001 divisions
S-418851 1.180 to 1.250 by 0.001 divisions

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TITLE 5100 - FIRE MANAGEMENT

*-Exhibit 1

APPROVED RETARDANTS 1/

AERIAL APPLICATION

Retardants	Mix Ratio
Fire-Trol 100	2.78 lbs/gal
Fire-Trol 931-L	4:1
Phos-Chek XA	1.14 lbs/gal
Phos-Chek XAF (Fugitive)	1.14 lbs/gal
Phos-Chek XA (Uncolored)	1.14 lbs/gal
Phos-Chek 259R (Regular)	1.14 & 1.60 lbs/gal
Phos-Chek 259W (Uncolored)	1.14 & 1.60 lbs/gal
Phos-Chek 259WX (Unthickened)	1.14 & 1.60 lbs/gal
Phos-Chek 259F (Fugitive)	1.14 & 1.60 lbs/gal

Note: All retardants have been tested and qualified only at specific use levels. Air retardants are not approved for use at mix ratios other than those shown. Administratively, Fire-Trol 100 and 931-L should be used only in buckets when applied by helicopter as they both cause excessive corrosion on magnesium. The above Phos-Chek retardants can be used in buckets or helitanks without excessive magnesium corrosion.

GROUND APPLICATION

Retardant	Mix Ratio
Fire-Trol 934-L	4:1
Phos-Chek 259R (Regular)	1.14 & 1.6 lbs/gal
Phos-Chek 259W (Uncolored)	1.14 & 1.6 lbs/gal
Phos-Chek 259WX (Uncolored, unthickened)	1.14 & 1.6 lbs/gal
Phos-Chek 259F (Fugitive)	1.14 & 1.6 lbs/gal

Note: All retardants have only been tested and qualified at specific use levels. Ground retardants are approved for varying mix ratios with full understanding corrosion rates may be increased.

1/ Only these retardants are approved for Forest Service use. NWCG has gone on record supporting use of only Forest Service approved retardants where specifications exist. Ground retardant use at other than approved mix ratios are by individual agency approval. -*